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PATENT

COVER FOR USE WITH AN INFLATABLE MODULAR STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a cover for use with an inflatable modular structure. The inflatable modular structure can be used as a spaced based platform or a habitat for use on a planet or other extraterrestrial body.

2. Description of the Prior Art

Inflatable modular structures are well known in the art as typified, for example, by U.S. patent No. 6,439,508 to Taylor, U.S. patent No. 6,231,010 to Schneider, et al, and U.S. patent No. 6,547,189 to Raboin, et al.

A major advantage to inflatable structures is that while the internal volume of a typical rigid hulled craft does not vary once deployed into space, the opposite is true for the inflatable structure. Once deployed into orbit, or to an extraterrestrial mass, the inside of the inflatable structure is filled with gas or air. The

1 flexible hull, or shell, expands in response to the gas  
2 and, as a result, the internal volume of the inflatable  
3 structure increases. Thus, the internal volume of an  
4 inflated structure having a flexible hull becomes  
5 substantially larger than the volume of a solid hulled  
6 structure where both structures have a similar launch  
7 payload volume.

8 This fact translates into a significant cost savings.  
9 A single inflatable structure can provide an internal  
10 volume equivalent to a number of solid hulled structures.  
11 With present costs at approximately \$10,000.00 to deploy a  
12 single pound of payload into space, a single launch of an  
13 inflatable module would provide a volume comparable to a  
14 number of launches containing rigid hulled structures.  
15 Couple this with the fact that many launch payloads can be  
16 several tons in weight, it is immediately apparent that a  
17 reduced number of launches saves a considerable amount of  
18 money.

19 While inflatable structures offer a number of  
20 advantages to less flexible structures, there are, however,  
21 technological challenges to deploying an inflatable module.  
22 For example, the flexible hull must be collapsible so that  
23 the module can fit into payload compartment of a launch  
24 vehicle and secured in place as to prevent unwanted effects  
25 arising from the acceleration of a launch on an unsecured  
26 mass. This is referred to as the pre-deployment  
27 configuration and storage of the hull at this stage should  
28 be done in a way such that the launch should not damage the  
29 hull.

30 A typical flexible hull has a number of layers. The  
31 internal surface is usually composed of an air bladder.  
32 The air bladder acts as a barrier to keep gas internal to

1 the module from escaping into space. A typical air bladder  
2 is not very thick and to function optimally it cannot have  
3 any leaks. When compacted for launch, it is important that  
4 the bladder does not come into contact with surfaces that  
5 could damage the hull.

6 An inflatable structure usually has a central core.  
7 The core is most often solid and runs the longitudinal  
8 length of the module. The core acts as a backbone to the  
9 structure and assists in, among other things, providing the  
10 shape to the structure and a framework for securing  
11 equipment.

12 To reduce the weight of the module, the core does not  
13 take the form of a solid hull. Rather, the core can be  
14 comprised of distal ends joined by a number of connecting  
15 elements such as longerons. In this form, the core is not  
16 designed to cooperate with a collapsed flexible hull. The  
17 core could have sharp edges or other protrusions that could  
18 damage the bladder of the hull.

19 At the launch stage, the bladder must be secured about  
20 the core in such a way as to minimize the opportunity for  
21 perforations, punctures, and tears in the bladder. One way  
22 to reduce the chance of damaging the bladder is to place a  
23 relatively smooth surface on the outside of the core so  
24 that the flexible hull could be folded around the surface  
25 without making contact with the core. The relatively  
26 smooth surface would be connected to the core and  
27 substantially surround the core to provide protection and  
28 support for the bladder. This surface could be part of a  
29 cover that is adapted to work with the core.

30 Another issue concerning the flexible hull is the use  
31 of windows. It is not unusual for a structure to have at  
32 least one window if not more integral to the flexible hull.

1 As a flexible hull is usually comprised of a number of  
2 layers including, but not limited to, an orbital debris  
3 shield, a restraint layer, and a bladder, there must be an  
4 opening through each layer for viewing through the window.  
5 Furthermore, the window would be secured to at least one  
6 layer of the hull. When collapsing the hull for the launch  
7 configuration, care must be taken to insure that the window  
8 is properly indexed in relation to the rest of the hull  
9 (thereby minimizing the tension between the window and hull  
10 while collapsing the hull) and that the window does not  
11 break due to the forces exerted on the smooth surface of  
12 the cover.

13 This could be accomplished in a number of ways. The  
14 smooth surface of the cover can be partially flexible to  
15 bend to a degree rather than being rigid. Also, a buffer  
16 material such as rubber can be placed between the window  
17 and the smooth surface. As to properly indexing the window  
18 in relation to the rest of the hull, the smooth surface may  
19 have an access port, opening, or a hingable structure such  
20 as a door. The opening can be used to insure that the  
21 window is in the correct location and then the opening  
22 closed to provide a further degree of support.

23 One potential drawback to this approach arises due to  
24 the fact that the cover would restrict access from the core  
25 to the internal volume of the structure when the hull  
26 becomes inflated. Thus, whatever form the cover takes, it  
27 must be removable from the core to allow access to the full  
28 internal volume created by the hull when the module is  
29 deployed.

30 Another challenge lies in the characteristic of the  
31 internal surface of the flexible hull. While a rigid hull  
32 can function to secure equipment to the inside of a solid

1 hull, the inside of the flexible hull is not so functional.  
2 Typically, the bladder forms the inside surface of an  
3 inflatable structure. The bladder does not have the  
4 structural qualities of a solid hull.

5 While the micro-gravity condition in space does not  
6 require the bladder to support the full weight of an item  
7 that may be attached to the surface of the bladder,  
8 nevertheless whatever comes into contact with the bladder  
9 might experience forces from other sources that could  
10 damage the bladder. One answer to this problem would be to  
11 secure a large panel to the inside surface of the bladder  
12 that conforms to the surface of the bladder and can support  
13 equipment without the equipment coming into contact with  
14 the bladder. The panel would serve to protect the bladder  
15 from contact with potentially damaging items and provide a  
16 foundation for securing items, such as equipment, in place.

17 Yet another challenge exists in the storage of  
18 materials and equipment at launch. While an inflatable  
19 module usually has a solid core, this does not mean that  
20 the core alone can function to store all the items needed  
21 in the structure. Furthermore, it may be necessary to  
22 distribute the weight at launch such that the core would  
23 not be an optimum place to contain storage items.

24 What is needed is a cover to provide a smooth surface  
25 for folding the bladder and flexible hull in the pre-  
26 deployed configuration. The cover would be substantially  
27 hollow for storing items prior to launch and during a  
28 mission. Further, the cover would be removable from the  
29 core after launch and during deployment. Finally, the  
30 surface of the cover would be contoured to conform to the  
31 inside surface of the bladder and securable to the bladder

1 to protect the bladder and to act as a foundation for  
2 securing equipment, materials, or other items as needed.

### 3 SUMMARY OF THE INVENTION

4 This invention is directed to a cover for a modular  
5 structure. The inflatable modular structure has a core  
6 with at least two longerons and an inflatable shell and the  
7 inflatable shell has an internal surface that generally  
8 encloses both the longerons and a plurality of covers. The  
9 core has a plurality of attachment elements cooperating  
10 with the covers such that each cover is releasably attached  
11 to the core in the pre-deployed configuration. In that  
12 configuration the inflatable shell is folded over, and  
13 secured to, the covers such that the covers provide a  
14 measure of protection for the shell so that the shell does  
15 not come into contact with the core. In the deployed  
16 configuration the inflatable shell is pumped up with air  
17 and the covers are released from the core and removably  
18 attached to a plurality of affixing members disposed on the  
19 inside surface of the inflatable shell such that the covers  
20 serve as a foundation for securing items in place.

21 The cover has a first segment having a longitudinal  
22 axis, an interior surface, and having an arcuate exterior  
23 surface along the length of the longitudinal axis. The  
24 arcuate exterior surface of the first segment is adapted to  
25 provide support and protection for the folded inflatable  
26 shell during the pre-deployed configuration. The arcuate  
27 surface also has at least one affixing member for  
28 cooperating with an affixing member on the interior surface  
29 of the inflatable shell such that the arcuate exterior  
30 surface is removably attached to the interior surface of  
31 the inflatable shell during the deployed configuration.

1        There is also a second segment of the cover that has a  
2 substantially flat surface. The second segment is adapted  
3 to substantially secure items in place when the arcuate  
4 exterior surface is fastened to the interior surface of the  
5 inflatable shell in the deployed configuration.

6        Along with the first and second segments, the cover  
7 has a plurality of ribs disposed between, and joined to,  
8 the inner surface of the first segment and the  
9 substantially flat surface of the second segment. There  
10 are a number of attachment elements disposed on the ribs  
11 adapted to cooperate with the attachment elements on the  
12 core such that the cover is releasably attached to the core  
13 in the pre-deployed configuration.

#### 14 BRIEF DESCRIPTION OF THE DRAWINGS

15        Fig. 1 is an isometric view of the top of a cover;

16        Fig. 1a is an isometric view of the top of a cover;

17        Fig. 1b is an isometric view of a cover showing  
18 attachment elements;

19        Fig. 1c is an exploded view of corresponding  
20 attachment elements;

21        Fig. 1d is a partial isometric view of a cover on two  
22 longerons;

23        Fig. 1e is a partial isometric view of a cover  
24 attached to braces;

25        Fig. 2 is a partial isometric view of a cover on two  
26 longerons;

27        Fig. 2a is an isometric view of the core with covers;

28        Fig. 3 is a cross-sectional view of the core

29        Fig. 4; is a cross-sectional view of the core with an  
30 inflatable shell in the pre-deployed configuration;

31        Fig. 5 is a cross-sectional view of the core with the  
32 inflatable shell in the deployed configuration;

1        Fig. 6 is a cross-sectional view of the core with the  
2 covers in the deployed configuration;

3        Fig. 6a is a side view of a cover attached to the  
4 internal surface of an inflatable shell;

5        Fig. 6b is a side view of a cover attached to the  
6 internal surface of an inflatable shell;

7        Fig. 6c is an isometric view of a cover with items  
8 secured in place;

9        Fig. 7 is an isometric view of a cover identifying a  
10 door on the arcuate surface;

11       Fig. 8 is an isometric view of a cover identifying a  
12 door on the second segment; and

13       Fig. 9 is a cross-sectional view of the cover in  
14 contact with a window;

#### 15 DETAILED DESCRIPTION OF THE DRAWINGS

16       The present invention may best be understood by  
17 reference to the following description taken in conjunction  
18 with the accompanying drawings. Fig. 1 is an isometric  
19 view of a cover 100. The first segment 102 has an arcuate,  
20 or convex, exterior surface 104 and an interior surface  
21 106. A second segment 108 is generally flat and is  
22 opposite to the first segment 102. A number of ribs 110  
23 are secured to the interior surface 106 of the first  
24 segment 102 and the second segment 108. In the preferred  
25 embodiment, the first segment 102, second segment 108 and  
26 ribs 110 are made of a rigid material. The material is a  
27 metal such as aluminum and the ribs 110, interior surface  
28 106 and second segment 108 are joined by know techniques  
29 such as welding or an adhesive materials. In the preferred  
30 embodiment, the exterior surface 104 is thin enough to  
31 allow for some flexibility. This is not, however, a  
32 limitation to the present invention and other materials,



1 metal and non-metal composites of varying thickness can be  
2 used. In the preferred embodiment, the cover 100 is  
3 substantially hollow.

4 Turning to Fig. 1a, the longitudinal axis 112 is shown  
5 exemplifying how the arcuate exterior surface 104 is  
6 perpendicular to the axis 112. In Fig. 1b, attachment  
7 elements 114 are secured to the ribs 110. In the preferred  
8 embodiment, the attachment element is a plate with a hole.  
9 Fig. 1c shows an attachment element 114 on the rib 110 and  
10 a corresponding attachment element 116 disposed on a  
11 longeron 118. The longeron 118 attachment element 116 in  
12 the preferred embodiment is a pair of opposing plates with  
13 holes that receive the rib 110 attachment element 114. In  
14 this configuration, attachment element 114 is sandwiched  
15 between the plates of attachment element 116. In this way,  
16 the holes align where a releasable pin 120 can be inserted  
17 through the holes to secure the cover 100 to the longeron  
18 118.

19 The pin 120 can be released by an operator. This  
20 contemplates a pin that can be removed by mechanically by a  
21 crewmember or the use of an electromechanical device. The  
22 figure identifies attachment element 116 at one possible  
23 location on the longeron 118. However, attachment elements  
24 114 and 116 can be oriented to cooperate on other locations  
25 on the longeron and the rib. The attachment elements 114  
26 and 166 and the pin 120 are used in conjunction to allow  
27 the cover 110 to be releasably attached to the core in the  
28 pre-deployed configuration.

29 As shown in Fig. 1d, the cover fits over two adjacent  
30 longerons 118. Fig. 1e depicts the situation where a brace  
31 122 has an attachment element 116 that cooperates with the  
32 rib 110 attachment element 114. The attachment elements

1 can also include latching mechanisms and other well-known  
2 mechanical and electromechanical devices for securing the  
3 cover to the longerons or braces. Figs. 1d and 1e show the  
4 cover attached to braces and longerons. That is because  
5 the core in the preferred embodiment utilizes. Other core  
6 configurations may dictate that the covers be attached to  
7 other support structures not identified in these figures.

8 Addressing Fig. 2, a cover 100 is shown with the core  
9 of an inflatable modular structure 124. The core 124 in  
10 this figure is comprised of a number of longerons 116,  
11 braces 122, and opposing distal ends 126. This is the  
12 preferred embodiment of the core 124. In this  
13 configuration, the cover 100 extends over two adjacent  
14 longerons 118. Fig. 2a shows the core 124 with a number of  
15 covers 100 extending substantially the length of the  
16 longerons. Fig. 3 is a cross section of the core 124 and  
17 shows how a number of covers 100 would be used in the  
18 preferred embodiment. As shown in Fig. 3, the width of the  
19 covers 128 extends substantially to the outer edges of each  
20 longeron 130.

21 Turning to Fig. 4, the inflatable shell 132 has an  
22 internal surface 134 that surrounds or generally encloses  
23 the longerons 118 of the core and a number of covers 100.  
24 Since the inflatable shell is attached to the distal ends  
25 and does not completely cover the distal ends, but rather  
26 the longerons 116, the shell 132 is said to generally  
27 enclose the core. It is also correct to state that the  
28 shell 132 generally encloses the longerons 118 as the  
29 longerons may extend into the distal ends in alternate  
30 embodiment. The shell 132 is usually comprised of a number  
31 of layers including, but not limited to, an orbital debris  
32 shield, a restraint layer, and a bladder. While these

1 layers are not displayed herein, they are referenced to  
2 indicate that the shell 132 is not limited to a particular  
3 set of layers or construction.

4 Fig.4 also depicts how the shell 132 can be folded  
5 over the covers 100. The number of folds depends upon a  
6 number of variables such as the thickness of the shell 132  
7 and the overall dimensions of the structure. Once folded,  
8 the shell 132 can be secured in place by any number of  
9 convention means including, but not limited to, being tied  
10 with straps. The covers 100 insulate the shell 132 from  
11 coming into contact with the core including the longerons  
12 118. The arched surface of the cover 104 provides a  
13 relatively smooth and supportive structure for the folded  
14 shell. When the shell 126 is folded over the covers 100  
15 and secured into place, the inflatable modular structure  
16 would be in the pre-deployed configuration. In this  
17 configuration, the shell and core would be secured to fit  
18 into the payload section of a launch vehicle.

19 Fig. 5 depicts the inflatable shell 132 filled with  
20 air and expanded to its fullest form. This would be the  
21 case where the modular structure was deployed into space or  
22 an extraterrestrial mass and inflated. This is the  
23 deployed configuration.

24 Now addressing Fig.6, in the deployed configuration,  
25 the covers are placed on the internal surface of the  
26 flexible shell 134. Fig. 6a shows the interaction between  
27 an affixing member 136 attached to the internal surface 134  
28 and an affixing member 138 on the arcuate surface 104 of  
29 the cover 100. The affixing member 138 on the arcuate  
30 surface is referred to as the first affixing member and the  
31 affixing member 136 on the internal surface is referred to  
32 as the second affixing member. The figure shows how the

1 arc of the arcuate surface 104 conforms to the arc on the  
2 internal surface of the flexible shell 134. This  
3 exemplifies the preferred embodiment. Further, the  
4 affixing members run along the longitudinal axis of the  
5 cover 100. Fig. 6b shows the affixing members running  
6 perpendicular to the longitudinal axis of the cover 100.  
7 This is the preferred embodiment.

8 In the preferred embodiment, the affixing members 136  
9 and 138 are made of Velcro. However, other types of  
10 affixing members such as, but not limited to, magnetic  
11 strips could be used. In any case, the cover 100 is  
12 removably attached in this way to the internal surface 134.

13 Once the cover 100 is removably secured in place on  
14 the internal surface of the shell 134, the cover can be  
15 used to secure other items in place. This is exemplified  
16 in Fig. 6c. The second segment 108 of the cover 100 is  
17 shown with items 134 attached to the segment 108.  
18 Attachment can be accomplished by a number of conventional  
19 means including, but not limited to, the use of Velcro  
20 fasteners, hooks and eyelets, bolts and screws, and  
21 magnetic strips.

22 Turning now to Fig. 7, the cover 100 can include an  
23 access opening 142 that is identified in the figure as a  
24 door on the first segment 102. This is the preferred  
25 embodiment, however the access opening can take other forms  
26 such as a sliding door or removable panel. In Fig. 8 the  
27 second segment 108 is shown with an access opening 144  
28 depicted as a hingable door. Again, this is the preferred  
29 embodiment for an access opening, however the access  
30 opening can take other forms such as a sliding door or  
31 removable panel. The access openings, in this case the

1 doors, serve multiple purposes. First, they allow access  
2 into the cover 100 for storing and retrieving items.

3 Another purpose of the access openings is shown in  
4 Fig. 9. A typical module will have at least one window 146  
5 integrated with the flexible shell 132. When the shell 132  
6 is folded into the pre-deployed configuration, care must be  
7 taken to locate the window 146 in a position such that the  
8 folding will not damage the window 146. When access  
9 openings 142 and 144 are open, the exact location of the  
10 window can be determined and the folding can be done such  
11 that the window 146 is less likely to be damaged. In the  
12 figure, the doors hinge by any number of known conventional  
13 hinging means and can be secured in place by the use of  
14 such items as bolts, locks, and latches in conjunction with  
15 the cover.

16 There has thus been described a novel cover for use  
17 with an inflatable modular structure. It is important to  
18 note that many configurations can be constructed from the  
19 ideas presented. The foregoing disclosure and description  
20 of the invention is illustrative and explanatory thereof  
21 and thus, nothing in the specification should be imported  
22 to limit the scope of the claims. Also, the scope of the  
23 invention is not intended to be limited to those  
24 embodiments described and includes equivalents thereto. It  
25 would be recognized by one skilled in the art the following  
26 claims would encompass a number of embodiments of the  
27 invention disclosed and claimed herein.